Appendix A

Calmet Code Changes

To defeat vertical extrapolation in Step 2 wind field development (while leaving in for initial guess), the following section of Calmet (Version 5.0, Level 970825) Subroutine DIAGNO was changed from:

```
   52 IF(ICALC.LT.0)  GO TO 850
C
C     EXTRAPOLATE SURFACE WINDS
C     EXTRAPOLATION OPTIONS:
C       1) IF IABS(IEXTRP)=1, THEN DO NOT EXTRAPOLATE FROM SURFACE DATA
C       2) IF IABS(IEXTRP)=2, THEN USE POWER LAW
C       3) IF IABS(IEXTRP)=3, THEN USE FEXTRP MULTIPLIER
C       4) IF       IEXTRP=4, THEN USE SIMILARITY THEORY
C       5) IF IEXTRP<=0, THEN DO NOT USE LEVEL 1 DATA FROM UA WINDS
C
      IF(IABS(IEXTRP).EQ.1) GO TO 91
```

to:

```
   52 IF(ICALC.LT.0)  GO TO 850
C
C     EXTRAPOLATE SURFACE WINDS
C     EXTRAPOLATION OPTIONS:
C       1) IF IABS(IEXTRP)=1, THEN DO NOT EXTRAPOLATE FROM SURFACE DATA
C       2) IF IABS(IEXTRP)=2, THEN USE POWER LAW
C       3) IF IABS(IEXTRP)=3, THEN USE FEXTRP MULTIPLIER
C       4) IF       IEXTRP=4, THEN USE SIMILARITY THEORY
C       5) IF IEXTRP<=0, THEN DO NOT USE LEVEL 1 DATA FROM UA WINDS
C
      go to 91
```

Some other changes were made to Calmet to accomodate visualization of wind, mixing ht, and stability class fields, but none of these affect results.

Appendix B

Calpuff Performance Evaluation

SFN 8094

NORTH DAKOTA DEPARTMENT OF HEALTH

INTRADEPARTMENTAL MEMORANDUM

FILE

MEMO TO	:	Dana K. Mount, P.E. Director, Division of Environmental Engineering
FROM	:	Steve Weber SW Rob White RW
RE	:	Evaluation of Calpuff Model Performance
DATE	:	March 4, 1999

Introduction

Performance of the Calpuff model (Version 5, Level 971107), as implemented by the NDDOH, was evaluated using SO_2 observations from the Dunn Center and Theodore Roosevelt National Park (TRNP) North Unit monitoring sites. Evaluation of model performance was desired because of the lack of consistent EPA guidance in implementation of the model, and in the selection of model technical options and other input parameters. The NDDOH implementation of Calpuff was based on in-house testing and experience, and on input from the National Park Service.

Consistent with the Calmet/Calpuff meteorological data set, the evaluation was conducted for the five-year period 1990-1994. Dan Harman provided hourly SO_2 observations from the Dunn Center and TRNP North Unit monitoring sites for this period. The SO_2 source inventory reflective of this period was provided by Air Quality Permitting staff. Selection of model technical options and other input parameters was consistent with intended NDDOH implementation of the model for regulatory Class I analyses.

Results of the Calpuff evaluation were very good, with virtually all of the predicted/observed ratios falling within the factor of two criteria prescribed by the EPA. Predicted values were within 50% of observed concentrations in 70 of 90 comparison cases. Predicted values were within 25% of observations in 45 of 90 cases.

Source Inventory

The evaluation analysis accounted for all SO_2 sources located within a reasonable distance of the two monitoring sites, and which operated during the 1990-1994 time frame. The inventory included all significant SO_2 sources within 250 km of the sites. Oil and gas production sources (i.e., treaters and flares) were also included. But because of their greater numbers and smaller size, the modeled inventory of oil and gas sources was limited to those located within 50 km of each monitoring site. SO_2 sources included in the evaluation analysis are identified in Table 1.

SO_2 emission rates for the significant North Dakota sources were determined separately for each year, based on actual emission reports for the period. Emission rates for out-of-state sources were not available on a yearly basis, so the SO_2 values used reflect the five-year average actual emission rate. Emission rates for oil and gas production sources were developed through the State Industrial Commission's Oil and Gas data base. The actual production data utilized reflected the period 1991-1992. The oil and gas production sources were screened to eliminate those with zero or minimal emissions.

Stack operating parameters (other than emission rate) used for North Dakota and out-of-state significant sources were consistent with those used in previous regulatory analyses. Stack operating parameters for oil and gas production sources were derived using procedures developed in the "Williston Basin Regional Air Quality Study", and modified using SCREEN3 flare procedures.

Calpuff Technical Options

Technical options deployed for the Calpuff evaluation analysis include:

- terrain effects
  (partial plume path adjustment)
- transitional plume rise
- stack-tip downwash
- vertical wind shear
  (oil and gas production sources only)
- puff splitting
  (significant sources only)
- chemical conversion
- dry deposition
- wet deposition
- dispersion coefficients from micrometerological variables
- partial plume penetration of inversion
- PDF (probability density function) used for dispersion under convective conditions

Selected options are based on state-of-the-art implementation of the model, input from the National Park Service, and substantial in-house sensitivity testing of the model. These options are consistent with intended NDDOH regulatory use of the model for Class I analyses.

Results

Calpuff was executed with source inventory and technical options noted above, for each year of meteorological data (1990-1994). Comparisons of model predictions with observed (monitored) concentrations are summarized in Tables 2 through 5. Comparisons are provided for the highest value in the yearly data sets (observed and predicted), the second-highest value in the yearly data sets, and the average of the ten highest values in the yearly data sets.

Consistent with EPA policy for evaluating model performance, the comparisons are not paired in time (of course the comparisons are paired in space, because only a single receptor, reflecting the exact monitoring location, was used).

Comparisons of absolute observed and predicted values are provided in Tables 2 and 3 (for Dunn Center and TRNP North sites, respectively) while predicted to observed ratios are provided in Tables 4 and 5. Note that Tables 4 and 5 also include predicted/observed ratios averaged over all five years.

Inspection of the comparisons in Tables 2 through 5 reveals that the capability of the Calpuff model to reproduce observed SO_2 concentrations is very good. With the exception of 1994 results for TRNP North Unit, all predicted to observed ratios are within the factor-of-two criteria prescribed by the EPA, and in most cases much better. Of the 90 comparisons made and documented in Tables 2 and 3, the predicted value was within 50% of the observed concentration in 70 cases, and the predicted value was within 25% of the observation in 45 cases.

For Dunn Center, overpredictions occur more often than underpredictions. But for TRNP North Unit, occurrence of overpredictions and underpredictions are nearly equal. The five-year-average summarization in Tables 4 and 5 suggests that overprediction tendency increases with longer averaging periods. Underpredictions for 1994 at TRNP North Unit may be connected to use of 1991-1992 emissions data for oil and gas production sources.

Conclusions

The evaluation of Calpuff performance at Dunn Center and TRNP North Unit monitoring sites indicates the model performs well, and within the factor-of-two criteria prescribed by the EPA. Though observations for some years and averages were underpredicted, it appears the Calpuff model, as implemented by the NDDOH, has no systematic bias toward over or underprediction. Therefore, the currently implemented version of Calpuff (Version 5, Level 971107) should be acceptable for NDDOH regulatory Class I modeling.

SW:saj
xc: Terry O'Clair
Tom Bachman
Joe Cicha

TABLE 1
Source Inventory (SO_2)

Significant North Dakota Sources:

- Coal Creek Generating Station
- Antelope Valley Generating Station
- Coyote Generating Station
- Leland Olds Generating Station
- Stanton Generating Station
- Milton R. Young Generating Station
- Heskett Generating Station
- Great Plains Synfuels Plant
- Little Knife Gas Processing Plant
- Grasslands Gas Processing Plant (i.e., McKenzie County Gas Plant)
- Tioga Gas Processing Plant
- Temple Gas Processing Plant
- T.R. Gas Processing Plant
- Amoco Mandan Refinery

Significant Out-of-State Sources:

- Colstrip Generating Station (Montana)
- MDU Sidney Generating Station (Montana)
- CELP Boiler (Montana)
- Boundary Dam Generating Station (Canada)
- Shand Generating Station (Canada)

Oil and Gas Production Sources:

- All sources within 50 km of Dunn Center Monitoring Site
- All sources within 50 km of TRNP North Unit Monitoring Site

TABLE 2
Dunn Center Observations vs. Calpuff Predictions

	SO_2 Concentration ($\mu g/m^3$)					
	1-Hour		3-Hour		24-Hour	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
1990 Highest	104.8	103.6	44.5	64.7	13.2	21.9
2nd High	68.1	71.0	34.9	43.8	10.6	18.3
Ave. Top 10	49.8	57.9	29.3	41.7	9.5	15.7
1991 Highest	117.9	90.7	41.0	57.6	16.2	29.0
2nd High	44.5	78.8	32.3	51.2	9.5	16.2
Ave. Top 10	41.4	66.0	23.8	46.7	7.6	14.6
1992 Highest	73.4	70.6	51.5	49.4	20.2	15.9
2nd High	60.3	57.8	44.5	42.3	11.6	15.5
Ave. Top 10	52.1	54.4	34.5	38.0	9.6	13.2
1993 Highest	99.6	123.1	57.6	90.6	15.6	24.6
2nd High	78.6	82.4	54.1	51.5	13.8	18.1
Ave. Top 10	59.5	69.9	40.1	48.2	10.9	15.3
1994 Highest	112.7	111.1	102.2	81.4	17.4	21.2
2nd High	102.2	81.1	48.0	52.8	14.5	19.5
Ave. Top 10	75.7	64.5	42.5	45.8	12.2	15.2

TABLE 3
TRNP North Unit Observations vs. Calpuff Predictions

	SO_2 Concentration (µg/m^3)					
	1-Hour		3-Hour		24-Hour	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
1990 Highest	55.0	39.9	33.2	34.9	12.4	14.4
2nd High	52.4	36.1	33.2	34.1	9.7	13.0
Ave. Top 10	40.1	34.7	25.9	24.9	8.6	10.3
1991 Highest	104.8	59.7	69.0	52.9	16.8	26.1
2nd High	57.6	57.0	28.8	46.4	12.6	17.2
Ave. Top 10	44.8	49.7	25.3	35.3	9.6	10.8
1992 Highest	52.4	55.3	34.9	41.0	10.7	17.4
2nd High	52.4	53.8	28.8	40.7	10.6	12.7
Ave. Top 10	39.6	46.5	24.5	34.5	8.9	10.5
1993 Highest	86.5	47.7	49.8	37.6	18.7	19.7
2nd High	65.5	41.4	48.9	37.4	12.9	12.9
Ave. Top 10	57.1	36.7	32.1	28.6	9.7	11.3
1994 Highest	128.4	40.8	62.9	34.2	20.4	13.4
2nd High	102.2	38.8	59.4	27.9	19.8	12.2
Ave. Top 10	71.0	34.0	44.2	25.2	15.0	9.5

TABLE 4
Predicted to Observed Concentration Ratios
Dunn Center Monitoring Site

	Predicted Conc./Observed Conc.		
	1-hour	**3-hour**	**24-hour**
1990Highest 2nd High Ave. Top 10	.99 1.04 1.16	1.45 1.25 1.42	1.66 1.73 1.65
1991 Highest 2nd High Ave. Top 10	.77 1.77 1.59	1.40 1.56 1.96	1.79 1.71 1.92
1992 Highest 2nd High Ave. Top 10	.96 .96 1.04	.96 .95 1.10	.79 1.34 1.33
1993 Highest 2nd High Ave. Top 10	1.24 1.05 1.17	1.57 .95 1.20	1.58 1.31 1.40
1994 Highest 2nd High Ave. Top 10	.99 .79 1.85	.80 1.10 1.08	1.22 1.34 1.25
5-year Ave. Highest 2nd High Ave. Top 10	.99 1.12 1.16	1.24 1.17 1.35	1.41 1.49 1.51

TABLE 5
Predicted to Observed Concentration Ratios
TRNP North Unit Monitoring Site

	Predicted Conc./Observed Conc.		
	1-hour	**3-hour**	**24-hour**
1990 Highest	.73	1.05	1.16
2nd High	.69	1.03	1.34
Ave. Top 10	.87	.96	1.20
1991 Highest	.57	.77	1.55
2nd High	.99	1.61	1.37
Ave. Top 10	1.11	1.40	1.13
1992 Highest	1.06	1.17	1.63
2nd High	1.03	1.41	1.20
Ave. Top 10	1.17	1.41	1.18
1993 Highest	.55	.76	1.05
2nd High	.63	.76	1.00
Ave. Top 10	.64	.89	1.16
1994 Highest	.32	.54	.66
2nd High	.38	.47	.62
Ave. Top 10	.48	.57	.63
5-year Ave. Highest	.65	.86	1.21
2nd High	.74	1.06	1.11
Ave. Top 10	.85	1.05	1.06